DOCUMENT RESUME

ED 140 526 EC 100 864

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TITLE Special Technology for Special Children: Computers as Prostheses to Serve Communication and Autonomy in the Education of Handicapped Children.

PUB DATE Apr 77

NOTE 70p.; Paper presented at the Annual Meeting of the American Educational Research Association (New York, New York, April 1977)

EDRS PRICE MF-$0.83 HC-$3.50 Plus Postage.

DESCRIPTORS Case Studies; *Communication Problems; Communication Skills; Computer Oriented Programs; *Computers; *Educational Technology; Exceptional Child Research; *Handicapped Children; Prostheses; *Recreational Activities; *Vocational Development

ABSTRACT

Reviewed are uses of the computer for communication and access to valuable educational, vocational, and recreational activities for a large class of people with serious communication problems such as deafness, autism, or severe physical handicaps. Some uses of the computer to benefit children immediately and directions for future research and development are suggested. Reported is pilot work with 10 multiply handicapped children (5 to 16 years old) which is noted to indicate hope for clinicians and teachers involved in the education and rehabilitation of such children. (IM)

SPECIAL TECHNOLOGY FOR SPECIAL CHILDREN

Computers as Prostheses to Serve Communication and Autonomy

in the

Education of Handicapped Children

Paul Goldenberg, April 1, 1977

All I wanted to do was talk. I used to think to myself

a day will come when I will be able to talk.

—Joseph Deacon

CONTENTS

0. Introduction:

Computers can be used to provide a radical improvement in the scope and quality of life for a large class of people whose autonomy is seriously diminished by handicaps such as deafness, autism or cerebral palsy.

The key idea is quite simple:

1. If you have voluntary control of any muscle, there currently exists a device that allows you to operate an electric typewriter

2. If you can control a typewriter, you can control a computer.

3. If you can control a computer, you have a powerful tool for communication and access to a vast range of valuable educational, vocational and recreational activities.

This paper focusses on the third step of this idea and grows out of work done at the Artificial Intelligence Laboratory of Massachusetts Institute of Technology. I greatfully acknowledge the philosophical contributions of Seymour Papert, director of the Logo Group at the laboratory. The work depended both on the technology that grew out of that philosophy and on the patience which that philosophy bred for a project that was often viewed as a distraction from the daily work of the Logo Group. I am also deeply indebted to the many Logo staff who helped in the design of the programs, the teaching and the documentation. In particular, Ellen Hildreth devoted considerable time and effort throughout the pilot studies in all phases of the project. Bruce Edwards handled most of the hardware and system software needs including the 180 mile emergency trip to make needed adjustments. Margaret Minsky, Ron Lebel, Henry Minsky and Jonathan Miller (the latter two, high school students) also contributed immensely to the project. I am also very greatful to the staff of The Crotched Mountain Center in Greenfield, New Hampshire -- in particular to Dan Steinberg whose energies kept bringing the Mountain to MIT until MIT was convinced to go to the mountain, and to Clinton Hilliard and Dr. Thomas Benson who had worked behind the scenes all along to support this project. Finally, there is Dr. Leo Geoffrion of the University of New Hampshire, who initially introduced me to Dan Steinberg and, with Dan, first shifted my attention to cerebral palsied children. Leo has also made numerous valuable intellectual and editorial contributions to the numberless drafts of this paper.

0.1 The Technology:

The application of electronic technology to aid communication for the severely handicapped person is not, relative to the technology itself, a new idea. Such aids have been reported as far back as 1957 [LaVoy 1957] and continue sporadically to appear in the literature. [Foulds and Gaddis 1975, Kafafian 1973, Luster and Vanderheiden 1974] Yet, despite the availability, variety and power of these devices -- and despite the age of some of them -- they are not yet well known or widely used. The most recent text on cerebral palsied children catalogued in the Boston Medical Library (part of the Harvard Library system) -- a 1974 text and resource book on their diagnosis, treatment and education -- makes no mention of electronic adaptive equipment, biofeedback or computers, *despite the presence of an entire chapter devoted to adaptive devices.* [Marks 1974] Where computers are used, their use is generally restricted to traditional computer aided instruction (CAI) models. There are two reports of educational/therapeutic uses of computers which do not fit the traditional

CAI model: Colby [1973] and Wier and Emanuel [1976] used the computer to catalyse communication in an autistic child. Despite the fact that much of Colby's rationale was reported five years ago [Colby 1971], the field still remains essentially *un*explored. Microprocessors are currently being added to the communication devices of Foulds and Vanderheiden, and there were some earlier efforts using computers as communication *aids* — *aids* rather than teachers — notable among them the work of Eulenberg and Tallman. Eulenberg has developed a speech prosthesis for non-vocal persons [Eulenberg 1976] and Tallman [Tallman 1976] has reported work on a computer aided communication system also for the non-vocal.

0.2 The Philosophy:

While it is certainly the case that cultural lag is at least part of the reason that these devices and techniques are neither in wide use nor, for the most part, in good use where they are known, it is my contention that an even more central problem is that our technological knowhow and philosophical outlooks are out of phase with each other.

What we try to accomplish -- and, perhaps more to the point, what we do not try to accomplish -- in habilitation and education of the handicapped is limited by what tools and techniques we have available and what ultimate success we expect is possible. It is also influenced by our view -- perhaps limited by our "normal" ethnocentrism -- of what a normal life must include. [Vernon and Makowsky 1969] Thus we may try for goals that are unrealistic and basically unnecessary, thereby frustrating the handicapped person. At the same time, we may reject goals which *seem to us* unattainable, but which could be expected with a more appropriate pedagogy or technology. It is probably just as well that I do not at the moment recall who it was who studied the effectiveness of music in improving the life of the long-term institutionalized mental patient by installing a stereo system and measuring the decrease in day-time pants-wetting. I have no doubt that they did, indeed, wet their pants less frequently, nor do I question the validity of that observation as a measure of the improvements of their lives -- not to mention the lives of their attendants. Certainly, one cannot question the importance of improving the lives of these people in any way, no matter how small. But contrast that research on improved living with the unfortunately less common view of Alan J. White, director of Project SEARCH. [HEW 1976]

> [Connecticut] has long had good programs to develop high creative potential among schoolchildren where it was found to exist, but only in the last year has a serious effort been made to look for these talents among children who have learning disabilities or emotional disturbances, or who are so crippled or palsied they cannot work or talk or hold a pencil to paper.
>
> By extensive and innovative testing, it was found that 12 percent of the handicapped children who were studied were gifted, roughly three times as many as in the general school population....
>
> The first surprise...was that two-thirds of the handicapped children...were capable of being tested. They had expected to be able to test a quarter of them at most. "This group has exceptional potential for growth and training and creative activity in the arts," Mr. White said. He suspected that families and teachers looked too seldom for the creative spark that might be there, because they spent all their agony and attention on the child's handicap. "They look for the defects and try to bring these up to strength," Mr. White said. "When a child does have a strength, the parents turn away from it and say, 'Thank goodness we don't have to do anything about that.' My feeling is we should be building on those strengths."

If Mozart had had a severe speech defect that was given more attention than his piano playing, we would never have heard of him! And how vast a segment of our population would be ineducable and unemployable and, no doubt, would seem intellectually and socially retarded if we, living in our current and complex society, were to lack the technology needed to create eyeglasses?

When we use the term "special needs" in reference to handicapped children, the hope is to convey an image of *capability* despite a dependency on some special services. But we frequently forget that it is the *services* and not their *needs* that are special. They begin with the same needs that anyone else has, but remain needy because we are emotionally or socially or technologically unready to meet those needs. One purpose of this paper will be to present an image of how a powerful computer technology can replace (or make unnecessary) some of the functions lost by a handicapped child and thus enrich and enhance his life. Several significant changes in current practice in special education are required; the technology makes such change both possible and promising. Specific examples from early pilot studies will illustrate these promises.

0.3 The Psychology:

These experiences are, in themselves, a source of new and valuable data about developmental processes. Much of current cognitive psychological theory is dominated by notions that passive observation of our environment is insufficient for learning, whether that learning is at the perceptual organizational level or whether it involves the so called higher cognitive processes. Indeed, serious problems are posed for this kind of theory when a severely physically handicapped person who has never passed normally through the sensory-motor stage of development is able after a few minutes time to match in style and detail the typical performance of a bright able-bodied fifth grader on a drawing task that requires considerable sensitivity to angle and dimension. If we are to understand Piaget properly, we must conclude that there is no such thing as the "passive" receipt of input from the environment. The perceiver (not receiver) is constantly selecting, processing and interpreting the stimuli, even if he is severely physically handicapped, and this is clearly a very active participation. Such has been our experience with a cerebral palsied adolescent, Jay, who has never had any useful functioning of his hands or arms (they are, in fact, strapped down to protect them and keep them out of his way), any use of his legs at all, or any speech. This observation becomes even more exciting when contrasted with the fact that Jay was for the first time demonstrating a high level of analytic and spacial ability and that he had been seen as retarded by several of the people who worked with him.[1]

After only three days in the Logo environment, Jay's achievements were already enough to make a difference to his life not only because his own image of himself as a learner had improved through a uniquely stimulating intellectual experience but because those who take care of him had seen a new dimension of his mind. Moreover, this fast and dramatic effect has by no means been limited to a few of the children with whom I worked. Having access to a powerful technology which one can control oneself and with which one can experiment and get direct and immediate feedback creates such a striking change in these children's sense of autonomy that it is almost not surprising that they typically perform "miracles" in their first few minutes working with the computer. An autistic adolescent observed to be mute and assumed to be deaf would speak his first words to the robot turtle, and child after child assumed to be mentally retarded would show clear evidence of normal or better intellectual ability. These surprises give important lessons in the handling of the severely handicapped individual and raise hard questions about currently accepted theory as well as clinical practice. I cannot hope to answer most of these questions here, but feel it essential that the evidence be presented so that these questions, which had previously been considered somewhat settled, can be opened up once again.

0.4 The Money:

It is estimated that about 100,000 victims of cerebral palsy are unable to communicate vocally as a result of their condition, and nearly 300,000 are unable to write. (These estimates do not include individuals who have central language impairments due, for example, to severe retardation, but include only those whose communication is limited at the motor level.) The technology required to ameliorate this communication handicap is all currently existing at least at the prototype level. None of it depends on designs or devices that could not be available within a matter of months. The human payoffs are, therefore, quite realistic. Furthermore, the expectable alternative for most of the severely physically handicapped individuals is a life of total support from governmental and private agencies. This cost, during schooling prior to age 21 is not uncommonly as high as $20,000 per year. After the age of majority the cost may go down, but with an expectably drastic cut in services as well. Estimates of lifetime support for an institutionalized, totally disabled person range upwards from $500,000. No matter how greatly we improve the educational and recreational aspects of the handicapped person's life, we are still only providing bandaids until we can solve the enormously tragic feeling of uselessness. A life vegetating expensively, even with stereo, just cannot compare with a self-supporting life of personally meaningful and satisfying activity. Jobs exist which depend more on the manipulation of *information* than on the manipulation of *things*, and which are therefore, in principle, accessible even to the most severely physically handicapped persons. Such jobs as editing, computer programming, reading specimens in a pathology lab and interpreting results or coding information from a slide for a computer, and being a reference librarian all require sensitivity, thought and personal expertise, but are not as dependent on the speed of the worker's output as they are on the competence of the worker's judgments. Radical experiments in work environment design must be attempted.

0.4 The Goals of This Paper:

The tremendous potential for revolutionizing evaluation and education for the handicapped has already been realized on a tiny scale in brief preliminary studies, and the impacts extend to the economics and sociology of handicaps as well as to developmental and cognitive psychology. Most important is the realistic promise of dignity and fulfillment to lives that are now crushed and wasted.

My ultimate intention is to present a picture of a technological and social environment within which such vast improvements in the quality of life of a handicapped individual can be realized that we can begin seeing his life as normal. In this paper, I will begin that job by reporting on our current experiences in pilot studies and will describe the educational spirit within which these studies were performed. The implications for clinical practice, cognitive theory and evaluation of potential should be clear and I will suggest some of the future research that seems needed.

1. Normal Needs and Special Needs:

1.1 Normal Needs:

1.11 A Budding Mozart:

Whatever it means to say that a person has the "potential" to be a musical composer, it is certainly clear that the person's mind needs opportunities not only for stimulation and activity, but for *feedback* from its activity in order to develop. Musical ideas that reside in that mind must be examined, refined and extended if they are to give birth or give way to new musical ideas. Think now! The assumption that a person has a musical mind is never made *a priori*. We always get some evidence of it. Perhaps it is first seen in the baby's dance, or perhaps in the child's faithful song. Sometimes it must await a more sophisticated communication. We do not suspect someone of a talent for composing unless he already has the performance ability to show it. And when the talent is discovered, the usual course of its development includes a protracted period of skills acquisition. Some expert music teachers incorporate composition experiences early in a child's musical education but performance skills remain the basics without which there can be no feedback. During this time, as every young musician knows, one spends vast time and effort preparing to play great music, less time actually playing any, and little or no time composing. Thus, we don't — and more to the point, neither does the budding Mozart — find out anything about the student's talents at composing music until rather late in his training. Such extensive preparation before being certain of one's interests can be a bad business investment. Some former children are thankful that their parents forced them through this stage. Others are not.

1.12 A Budding Anybody:

As a teacher, I want to help my students develop their autonomy. I am acutely aware that this goal is not achieved merely by offering them choices and options. Unless the child can *act* on the choices and unless the choices have significantly different consequences, merely *having the choices* cannot be meaningful. The problem is that there are so many options which a seven year old mind is capable of inventing, wanting and even understanding but which the seven year old body is totally unready for. Other options are prevented because of educational or experiential limitations. Examples abound. One child wants to experiment with music. He is unable to do so without musical skills. Another child is interested in planets and planetary orbits, but lacks the mathematical skills for looking abstractly at time and motion and lacks both physical skills and equipment to do much "playing" with the subject matter — other than copying from books. He is much more handicapped in what he can *do* than in what he can think about doing. A third child understands the principle behind an animated cartoon and has a clever "flip-book" cartoon idea living in his head, but doesn't have the patience to make hundreds of nearly identical drawings or the skill to make drawings that please him and do justice to the original idea. Many children (my former second graders, for example) are interested in anatomy, but are usually limited just to looking at pictures in a book because of the danger and difficulty of performing anatomical experiments such as dissections. Thus it is not only musical creativity but all creative work which is put off by seemingly interminable preparation and exercises.

The point, of course, is not to ignore skills acquisition, but to stimulate curiosity and intellectual growth and love for learning by providing exciting applications of these skills *as* they are acquired rather than waiting for a large number of skills before applying any. As schools attempt to incorporate some "casual learning" environments (e.g., outdoors play, museums, pretending, zoos, parents' workplaces,[8] movies, games, eating and watching TV) into their programs, children have more opportunities to mold their own activities and can thus stay closer to the frontiers of their own development, but there are still vast areas of potential involvement in which the child is generally, at best, just a spectator.

1.2 The Computer, Meeting Normal Needs -- Three Metaphors:

1.21 The Computer as Entertainer:

It is a common observation that computer programmers who have access to their machines after hours will often spend those extra hours -- even after a full day's work -- teaching the machine "tricks." They will teach it how to play tic-tac-toe or to simulate a rocket that the user is trying to land on the moon. They will teach it to play some friendly joke on a coworker, or to print Snoopy pictures on the line-printer. And they will bring their children to play with the marvelous toy. It is remarkable that this kind of playful and creative overtime is put in by programmers almost regardless of how much or how little they otherwise like their jobs. What is it about this toy that is so engaging? Perhaps it is the power to make it do one's bidding. Perhaps it is the opportunity to be involved in an otherwise inaccessible activity, such as landing a rocket on the moon. Perhaps it is the access to artistic creativity without having to have the artist's hands. Perhaps it is the challenge of solving tic-tac-toe so thoroughly that one can create an infallible playmate. Perhaps it is just the *spirit* of programming, one which regards non-working programs not as failures, but as unfinished products, things which can be fixed.

1.22 The Computer as Assistant:

The problems of the budding anybody seem not to exist during the computer programmer's game time. How can we put the power and opportunity and creative freedom and challenge and spirit of computer programming in the hands of a young child? To avoid pinning it all on another protracted skills-acquisition period, we must first develop a powerful computer language which a young child can easily learn. We must also consider how the computer should respond back to the child. If it can only print to the child, a child who does not enjoy reading is restricted in what he can do. But suppose the computer can also control a robot. The child can teach that robot how to wander about on the floor making a drawing of its path, or run an obstacle course, or knock over a tower of blocks or escape from a maze. Suppose the computer has a high-resolution graphics display and high-speed animation capabilities. Then it can make drawings on a TV screen at the child's instruction. By teaching the computer how to make the right drawings and when and where to display them on the TV screen, the child can create original animated cartoons. If the computer can also generate musical tones, the child can instruct the computer to accompany his cartoon with music or sound effects he composed. He can narrate the scene with printed text which captions the cartoon at the appropriate times. With the appropriate equipment he can even use computer generated speech, all of his own design. The possibilities for the development of self-expression are vast. Moreover, even the non-reading child can communicate with the computer, perhaps by speaking his commands directly to the computer, or by pressing buttons coded with pictures. The computer can speak its messages back to the child.

Designing and developing such a computer environment for normal school-age children has been one of the principle goals of the Logo Group at M.I.T. for the last several years, and considerable experience with a variety of children from local public elementary schools has shown us that the enthusiasm and creativity that we anticipated can, indeed, be expected.

1.23 The Computer as Animated Scratchpad:

In section 1.11, I suggested that a mind cannot develop in the total absence of feedback. There are also times when we get enough feedback to do a job well, but remain unaware of how much better we could do if the cost of that feedback were not so great. Consider creative or expository writing. We are accustomed to improving our composition over the course of a few discrete drafts. Every revision, even of spelling, requires a whole new draft with all of the retyping involved. Thus, student writers often find it more rewarding *not* to review their work than to try for a better grade. Heroic efforts (spending more than the usual time patiently rewriting an idea) are unusual and so the "talented" writers are those who can produce a satisfying result on the first or second draft. A computer which constantly displays the "current draft" on a TV screen and allows one to delete or add a paragraph in the middle or change the order of a few paragraphs or eliminate or switch words here and there *with no retyping* would make it possible to go through more of what we currently call "drafts" without the tedium and effort. Perhaps a child (or adult) who could not produce a beautifully written composition in three drafts could do it in twenty. If the twenty took less time to do than two drafts normally take, we would see far greater motivation to improve written work, and probably many more literate writers. In the same way, it may be that the scarcity of great musical composers is not because too few people have talented minds, but because too few have talented fingers.

1.3 Special Needs:

An adequate technology thus reduces the normal child's learning handicaps. The same computer environment is easily tailored to the physically handicapped user. Even though there is still room for clever work to find better methods of doing this, all of the really *basic* problems of making it possible for a severely physically handicapped non-vocal person to control a computer have already been solved by a number of other researchers [Luster and Vanderheiden 1974]. It is certainly not obvious that such a child need be any more handicapped at musical composition or architectural design than you or I once the problem of output and feedback is eliminated.

The deaf child's communication handicap slows down both input and feedback in English. Among those children fortunate enough to have been educated with sign language, the majority did not have it introduced to them as early as the hearing child's shared language began. Thus, even with sign language, we are handicapped in our ability to transmit to the child as complex an idea as he is capable of producing and manipulating in his head. But we *can* provide such a child with a computer environment in which the linguistic complexities are greatly reduced. The child can then begin to generate his own intellectually exciting and challenging problems and can thus explore at his cognitive and educational frontiers without *always* having to mediate that experience through his weakest link. Some preliminary observations suggest that the deaf child may have special abilities in certain kinds of spatial thinking. It is instructive to realize that his sign language has accustomed him to carving meaning out of space and has not so strictly constrained him to linearity as English does. Thus, in this area, his "handicap" is certainly irrelevant and may actually be an asset. The concern is to begin seeing what the child is especially capable of, rather than focussing on what he is incapable of doing.

The notion of a prosthetic device seems, at first, less apt when applied to the autistic child, but recall the above examples. Although the deaf child can deal with verbally mediated situations, he is certainly not at his best using that medium. The physically handicapped child is at a disadvantage when he must mediate interaction with the world through coordinated motor activity. In each case we bypass or ignore the weak communication modality and see very fast and exciting changes in the child. Similarly, the autistic child is not at his best when his contact with the world has to be mediated through people. Popular therapeutic practice attempts to force the child to make eye-contact and work through people more and more, but as an initial goal this may be as counter-productive and ego-demolishing as strict oralism often is to the profoundly and preverbally deaf child. A reasonable conjecture, and one for which good evidence is being found, is that the autistic child's best route back to the world of people may be through having the machine-world that he needs at first. Simple machines like phonographs and small mechanical toys are often very attractive to the autistic child, but they seldom offer rich enough possibilities to expand the child's world. At the very least, learning how to communicate with a computer teaches that communication works. Our recent experiences[2] and others [Colby 1973, Wier and Emanuel 1976] show that the computer experience can bridge the gap to human communication and catalyze spontaneous communicative efforts.

For the autistic or deaf or cerebral palsied child, whose autonomy is even more limited than the public school child's, the computer provides a tool for creative activity. Because it enables these special children to affect and control their world, and because it is a tool with which they can become proficient and show off their creativity, it offers them a powerful chance to develop their own feelings of self worth, to see themselves as learners and doers. For us it provides a window, perhaps our only clear window, into the child's mind. And, as it enables us to see more clearly into his thinking and creating, it serves the purpose not only of diagnosing, but of deeply understanding and working with the child.

1.4 Disordered Communication:

> Jonny[3] is a bright, friendly 14-year-old with athetoid cerebral palsy. His speech is labored but usually understandable. His arm and hand control is insufficient for all but the most gross movements. He talks comfortably of his abilities and disabilities, and is just as sensitive to those of his schoolmates. ("Do you know Jay? He's even more spastic than I am!"). Often as we worked together, he would make a suggestion about how to build or arrange a device for another child. He is particularly interested in designing aids for cerebral palsied people. He controls his own electric wheelchair, but he would prefer a non-electric one ("I don't get enough exercise with an electric wheelchair"). Standard hand-powered wheelchair designs have proved impractical for him, but he has invented one that he feels would be quite suitable. Although he can *imagine* the design of the chair, he cannot *draw* it. "Just give me a week with someone who will draw for me and I will tell him exactly what to draw."

Expressive communication is not limited to verbal or written behavior. We give travel directions with our hands, hum parts of tunes, and draw pictures and maps to help make our words clearer. When we speak, we rely so heavily on our facial expressions, verbal pauses and vocal inflections, that direct transcriptions of casually spoken messages are often extremely difficult to comprehend. Our written language is full of punctuation, underlinings and formal wordings in an attempt to replace the information that we normally convey *without* words.[4] But not even body language and gesture complete the picture. We communicate with our *environment*, too, and do so by *acting upon it*. Often these actions serve important interpersonal communication purposes. Without at least some voluntary motor control, there can be no communication.[5] Without fully intact motor coordination and volitional movement, some expressive communications will be impaired.

We regard serious abnormalities in sensation, perception, cognition, or motor control as handicaps in themselves. To the extent that they restrict our communication, they give rise to secondary handicaps. It is artificial to discuss these effects as if they were separate and distinct, but there can be no doubt that the impact of the communication breakdown on a person's quality of life is very grave, indeed. When the information we receive from any source is incomplete, unclear, ambiguous or contradictory, our comprehension of our situation suffers and our responses become inadequate or inappropriate, further breaking down the communication loop.

The expressive and receptive aspects of communication keep each other in tune. Although we must raise serious questions about the theories which suggest that all learning requires active participation there can be little doubt about the advantages that a complete feedback loop from *active involvement* has over "passive" information *input* from the environment. Any sensory, perceptual, cognitive, emotional or motor handicap alters or reduces the feedback loop.

From this point of view, the special needs of children may be even more striking than we had supposed. In the same way that we are handicapped in our ability to experiment with music, a child whose problems in motor control prevent him from talking, writing or typing is handicapped in his ability to experiment with language. If the development of our musical imagination and creativity depends on its use and, in particular, our feedback from its use, we can see how devastating the lack of linguistic feedback may be to a child. Mental development in general suffers functional retardation when a person can never *try out* his ideas and get feedback from the trials.

2. A Brief Philosophy of Computer Use with Handicapped Children:

2.1 Patching the Child vs. Patching the Environment:

2.11 Patching the Child:

When we lacked the technology to adapt an environment to a child, then we were forced to focus only on adapting the child to his environment. Thus, when hearing could not be restored to a deaf child by medical or electronic means, the primary goal became speech and speech-reading, the *most apparently normal* communication channels available. When a child's motor control was poor, then the primary goal, sometimes despite considerable pain to ourselves and the child, was to improve it. But despite the worthiness of good speech and motor control as ends in themselves, they are for most of us simply means to the real goal, a full and rich and satisfying life. The effort a child must put out to improve a physical skill is generally extremely hard to motivate unless the child can see some clear sign that the effort will pay off. An emphasis on patching the child is beneficial only as long as it is pursued with enough patience not to cause more frustration than growth and, more importantly, as long as some interim way for the child to regain and develop his autonomy is fostered -- and, of course, only so long as real improvement is regularly seen.

2.12 Patching the Environment:

John Eulenberg [Eulenberg 1976] referred to a handicap as a "sociological and technological artifact."

It is a sociological artifact to the extent that we see a person with glasses as normal, but a person with a hearing aid as handicapped. In our efforts to pursue the normal routes to education and growth, we may overlook aids that are already available. An electric toothbrush may be a luxury for a normal person, but for Lisa, who cannot open her mouth much and cannot hold it open reliably, it is an essential tool for dental hygiene. Yet no child on Lisa's ward owns one and no hospital or governmental regulation seems to mandate such purchases. The technology exists, but is not being used. Furthermore, those adaptations that make life more convenient for a handicapped individual are often not as readily accepted as aids for normal persons. Even the benificiaries sometimes come to regard special adaptations as second best.[6] The cosmetics of an aid for normal people -- let us say a remote control switch for the TV -- would never be ignored by the manufacturer, but similar consideration for the attractiveness of a device and the dignity of its user is not so universal in the design of aids for people identified as handicapped. A speech pathologist tells of his experience with two kinds of wheelchairs. When he travels about in his standard wheelchair and children look at him, their mothers would say "Don't look at that man; he's sick." When he travels on his bright yellow sleek electric motorized "golf-cart" wheelchair and children look at him, their mothers even encourage the curiosity.[7]

The handicap is a technological artifact as well. We are quite skilled at making aids to correct severely defective vision. Glasses are small, inexpensive, unobtrusive, attractive, portable and effective. Many people who wear glasses would be "lost without them" and utterly barred from the educational, vocational and recreational lives they now lead. We are not so skilled at making aids to correct even moderately defective hearing. Some hearing-impaired individuals are able to use an amplified telephone perfectly well without their hearing-aids, but cannot, even with the aids, understand relatively loud speech in daily person-to-person conversations without depending on lip-reading, gesture or heavy contextual cues. The hearing-aid technology is leaving needs unmet. Communication aids for the severely physically handicapped are at an even more primitive level. A rather large variety of devices currently exist, most of which require either that the handicapped person point to letters, words or phrases that are printed on a lap-board or select (without the need for pointing) from letters, words or phrases that cycle by on some sort of display. Success with these devices, despite our ability to personalize them considerably, still depends on the physical capabilities, motivation and language level of the user. But even success with this medium of communication generally provides text-production capability only and is therefore far from optimal.

2.2 Three Ways Computers can be Used in Education:

2.21 The Computer as Tutor:

Perhaps the most common non-bookkeeping use of the computer in education is as a private tutor. A program[8] is designed by teachers and programmers to lead a child through a sequence of steps to learn some desired behavior. Although the child may be an active member of the child-computer team, it is the child who is being programmed. The interaction is guided by the computer which generally initiates all of the transactions (poses a problem, asks a question, gives an instruction) and chooses its next course of action based on the child's response to the last one. Proponents of this use of the computer argue that the computer, unlike a person, is reliably patient, able to keep detailed and flawless records, and able to juggle those records to choose the smoothest path for the student's learning based on his past and current performance. This use of the computer might be called the *Hospital Model* of educational intervention. Within the Hospital Model, students are tested, screened and diagnosed. Weaknesses are identified and programs of remediation are prescribed. This model is prevalent even in settings where the most immediately visible and preemptive characteristic of the children is not some severe handicap.

Serious risks attend this model. Though perhaps practical for certain academic skill goals, computerized programmed learning streamlines an aspect of teaching which properly constitutes only a tiny fraction of the business in which students and teachers ought to be engaged. Moreover, it assumes, *a priori*, that the child is *not* the agent, but the patient. Thus, whenever our goal for a child is to build his autonomy and initiative, the model is counterproductive. At the best, progress toward autonomy is superficial; at the worst, it is undermined altogether.[9] For the handicapped person, the Hospital Model is a superfluous reminder of his own disabilities.

2.22 The Computer as Eyeglasses:

Unlike a tutor, eyeglasses have no agenda for the wearer. They contain no information for the wearer to learn and they don't try to teach. Yet they allow the wearer to do things that would otherwise be difficult, perhaps impossible. The computer allows a child to make an animated cartoon without requiring that he have the drawing skill in his hands; to experiment with musical ideas without requiring that he *first* gain competence at an instrument. The computer extends and amplifies the abilities of the person with normal needs. Again, one sees the same (and more) vast possibilities for people who have special needs.

The important distinction between the tutor metaphor and the eyeglasses metaphor is the shift of emphasis from programming oneself, to learning how to influence one's surroundings — from focussing inward, to focussing outward.

2.23 The Computer as Mirror:

A device which can sense extremely slight variations in an act we perform and can be programmed to recognize the fine distinctions between relevant and irrelevant variations can be used to provide very sensitive feedback on our performance. For example, a machine which draws distinctly different pictures depending on our pronunciation of a vowel can give more accurate feedback than our untrained (or deaf) ear can and thus is useful to guide us to correct pronunciation. [Nickerson and Stevens 1973, Nickerson, Kalikow and Stevens 1976] A device capable of identifying muscular activity even before we have been able to muster the strength or coordination to produce a visible movement can tell us when we are addressing the correct muscles. It will be easier to consider the applications of this kind of technology if I describe them in relation to a particular child who might benefit from them.

> Lisa is a 13 year old spastic cerebral palsied girl whose size and physical development make her appear about 9. Her voluntary movement (arms, legs and mouth) is extremely restricted in speed, range, accuracy and strength. She cannot sit herself up in bed, dress, feed herself, or control her wheelchair. She has a reflex grasp, but for practical use, she cannot grasp or hold anything. On occasion, she speaks, but seldom produces more than a high squeek. She has signs for "yes" and "no," and slowly and with great effort, she can point to words on her word board. Within the limitations of her ability to respond, Lisa shows that she can read, spell (including reasonable spelling for new words), arrange words in grammatical order and understand spoken language. Despite some early diagnoses as mentally retarded, a recent doctor's report begins with the words "This bright little girl," and most school and medical evaluations now agree that she may be quite bright.
>
> Lisa's physical abilities vary considerably from day to day with motivation apparently a key factor. This is perhaps not very surprising when we consider the payoffs Lisa receives for her

efforts. The mark of real autonomy depends on what options are open to one. For a child whose movements are uncoordinated but stronger than Lisa's, showing independence by doing *as much as possible without help* might be the clearest sign of autonomy. For Lisa, however, there is no independence to show. There is nothing of real salience in her life that she can do completely alone, so all of her efforts only serve to help the person she is dependent on. Thus, the greatest show of her autonomy, paradoxically, is to do *less* than she is capable of, to withhold the help that she can give, to use her own dependency to control others. The discrepancies between her best performances and her typical performance are great. Some people make generous allowances, but others say she is obstinate and lazy or even a deliberate con artist. The interpretations vary, but the observations are the same; she seems unmotivated and does less than she appears capable of.

In order to give Lisa appropriate care, we must consider both her physical abilities and her psychological state, her motivation. In school she appears not to use her word-board unless coerced into it. But, being the first to respond to a question asked in class is not a driving life issue for her. The major problem that she faces is that if people left her, she could not live at all. For Lisa, "making a living" consists not of academics, but of keeping around people who have taken physical care of her and whom she likes. Pointing to "kiss" or "thank you" or "I like you" in the latter context is something she does, apparently quite readily. If one follows the line of thinking still further, it costs Lisa effort to communicate, and the returns should be great if we expect her to make the investment. With a sufficiently friendly computer interface she could turn on or off a TV at will, drive her own wheelchair, select from and eventually create her own computer programs. The addition of efficient and satisfying communication to her life may have an avalanche of values.

Two novel input devices for the computer can be employed in exciting and creative ways as adjuncts to or replacements for other forms of therapy for handicapped individuals. One is the electromyometer (EMM) and the other is a speech analyzer.

The EMM provides accurate and continuous measurements of the electrical activity of a muscle or portion of a muscle. Properly used, it has helped patients learn to reduce muscular tension, control the processes leading to migraine headaches, reduce their blood pressure, and regulate circulation. Selective and sensitive response to the inputs from multiple biosensors is a job that is impractical or impossible for a human monitor, but easy for a computer. Clearly, the possibilities for using computers as intelligent monitors here are very rich. Research has shown that even some pathological CNS processes can be consciously controlled. This gives us hope that severely motor handicapped patients can learn to control their pathological motor patterns and regain use of limbs that had been functionally lost for years. [Brudny et al. 1974] The preliminary results have been very encouraging. With research and intelligent processing of these signals, it may be possible to use this kind of signaling as a voluntary input to the computer in a more random access way than is currently seen in the myoelectric switches used with scanning-type input devices.

Research grounded in the belief that physical and mental skills are highly similar has produced some observations that lead to a new understanding of the development and facilitation of physical skills. [Austin 1974] For instance, people at the Logo Group have taught others to juggle without either touching them or demonstrating the skill. The notion that a complex physical procedure such as juggling can be decomposed into smaller easy-to-learn sub-procedures and can be communicated verbally (intellectually) has a message for the habilitation of Lisa and children like her. Locating an object in space and grasping it is a complex procedure. We can see babies practicing the "primitives" and sub-procedures which, combined properly, will lead to Reach-and-Grasp. What about a child like Lisa? Such a child gets inadequate feedback either because she cannot practice well (she cannot make enough of a movement to get clear visual and proprioceptive information back) or because so much extraneous movement is occurring that it is too difficult to determine what part of the feedback is signal and what part noise. Teachers who have a clear understanding of how physical skills are built up and who can provide accurate sensitive feedback may be able to help Lisa learn to Reach-and-Grasp much the way I could learn to juggle. The fact that Reach-and-Grasp is not "natural" to her may be no more of a hindrance than the fact that juggling is not natural to me.

Although this is another application of the Hospital Model -- the agenda is not in the patient -- these goals are of obviously great value to a person such as Lisa and are so intrinsically tied up with her own experience of autonomy that it becomes academic to object that the therapy she receives explicitly assumes her dependency. Lisa is, in fact, highly dependent on others for almost all of her care. Even so, some of the risks of the Hospital Model still apply and it is worth trying to avoid those risks. As liberating an experience as it is to gain new control of oneself, it must have even greater significance to see that one can use this self-control to have predictable and desired effects on one's environment. In order for Lisa to communicate with the computer, she must perform some voluntary act. The EMM allows us to choose sensitively among the acts that Lisa performs to find one that both allows her the optimal access to the computer and communication, and practices a muscular act that is beneficial for her. Furthermore, it allows us to select a muscular act which may not yet be capable of serving Lisa in other ways. Thus, we are not sugar coating an exercise to make it fun, but taking an enjoyable and beneficial activity and adding to it, for free, another benefit. The philosophical distinction, I believe, is important.

Speech analysis technology offers similar possibilities. There exist devides which are capable of learning to recognize the user's vocal productions (whatever they are) and responding in a different way to each vocalization. For Lisa, consistency and repeatability are both difficult, but not nearly so difficult as is clear articulation. Full and comprehensible speech is, at present, an unrealistic, frustrating and probably discouraging goal for Lisa, but it seems quite likely that she can learn to produce enough distinct sounds to use for communication. If she had a device that could decode her vocalizations and, more to the point, was always with her -- perhaps installed in her wheelchair -- several benefits might be derived. The immediate benefit is the new modality with which she can control things -- whether that be moving her wheelchair or causing a voice-producing device to say the words she had wanted to say with her own mouth. A secondary benefit comes from the feeling that *her voice* was adequate to the task. If she can make five distinct sounds, and can see, herself, that she was successful at that, she has the motivation of success to try for a sixth sound.

3. Communicating with the Computer:

3.1 Principles of Inputting:

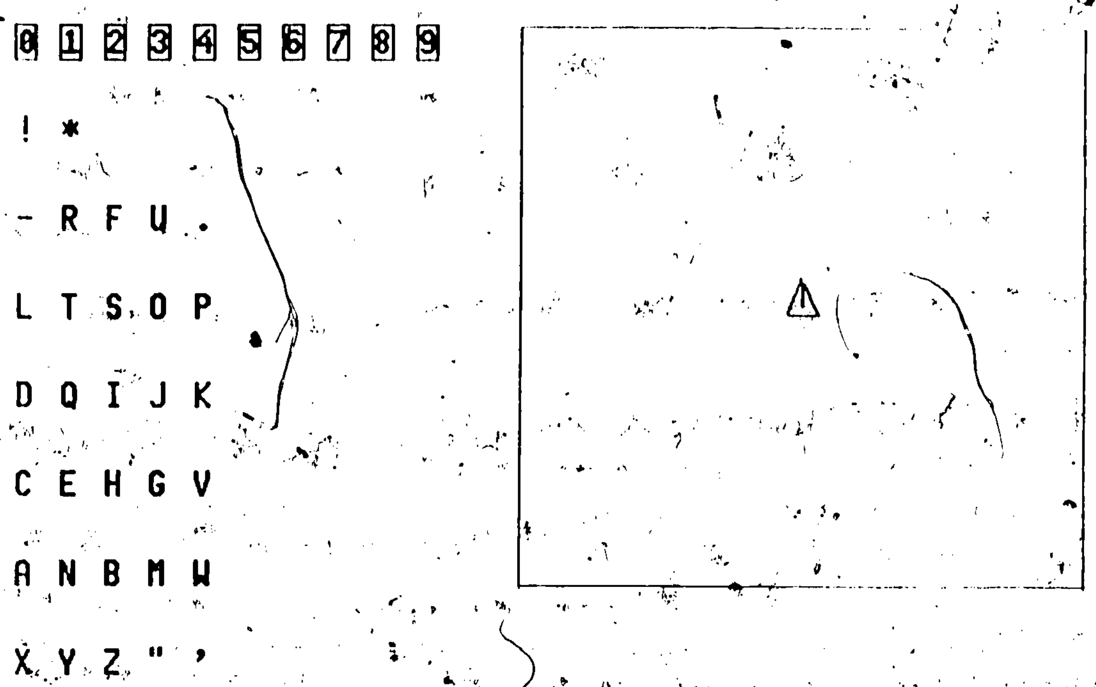
The computer is capable of recognizing a certain fixed number of signals. We may assign these signals any particular meaning we like, e.g., letters, numbers and punctuation, or whole commands. It may have been taught to understand combinations of these symbols. For example, if the basic signals stand for letters, the computer may have been taught also to understand words. To communicate with the computer, we must be able to send it the basic signals it recognizes, which must then be arranged for us on a kind of menu. For the most part, only two systems for arranging the items on the menu are in use; arrangements in space and arrangements in time.

3.11 Arrangements in Space:

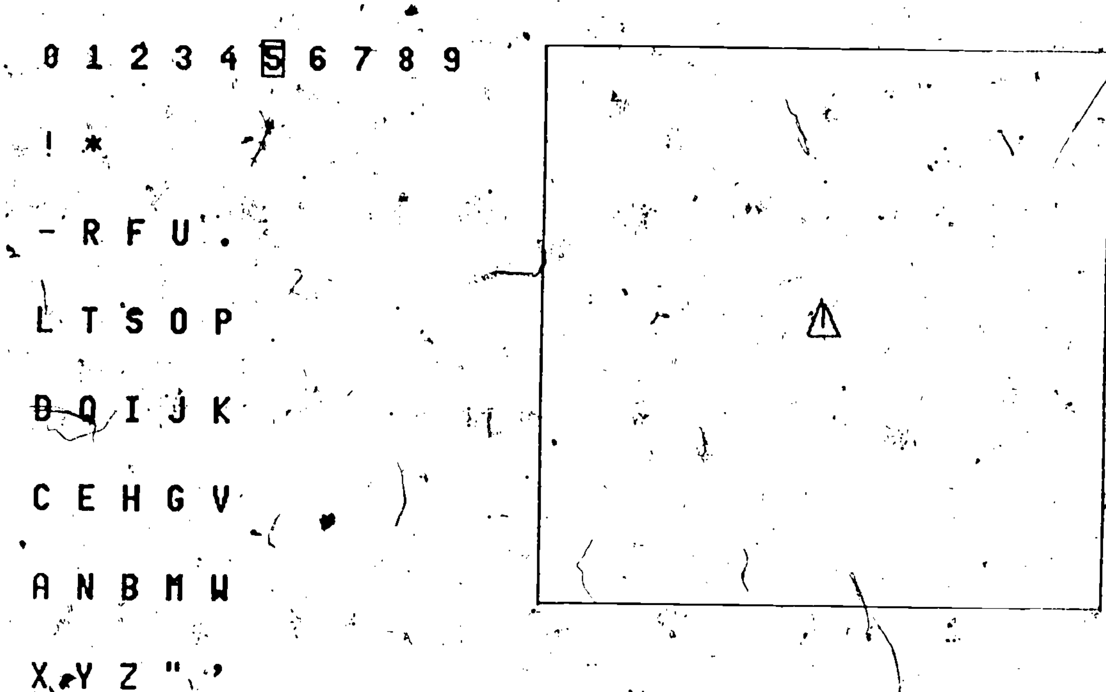
The choices are laid out in some convenient array with one switch per item and the user selects the items directly by activating the appropriate switch. A typewriter is such a system, where the information one can send includes numbers, letters and special symbols, spaces, etc. Each character has its own key and one aims and presses. Automatic elevators use the same kind of input system. The primary advantage is that all of the options are visible at once and the user has "random access" to the choices, that is, he can get any one as quickly and easily as any other choice. The requirements are that one has enough room for all of the options to be presented and that the user have the ability to aim with speed adequate to make the selection practical.

3.12 Arrangements in Time:

Again, the choices are laid out in some convenient array, but this time there is only *one* switch controlling *all* of the choices. The switch is tailored to the abilities of the user. The user may signal by bumping the switch, e.g., with his hand, or knee, or by blowing on it, or by making a vocal noise, or by flicking it with his tongue or by letting an EMM recognize the twitching of his eyebrow. Some kind of indicator (an arrow or a light) moves past each option and cycles back to the beginning when it has reached the end of the list. The user decides which option he wants and waits until the indicator offers that particular option. Then the user activates the switch, selecting that option and sending it to the computer. Modifications of the basic idea can be made when needed. For example, if there are very many options, it is impractical to wait for all to cycle by — as is the case if we wanted to make available all of the letters in the alphabet and numbers and punctuation as well. In situations like this, the options may be arranged in a two-dimensional array. The indicator (in this case, boxes) cycles by the rows allowing the user first to signal which row the desired character is in. (Fig 3.1) Then the indicator cycles within that row until the user sends another signal indicating the desired letter. (Fig 3.2)



Selecting the row figure 3.1



Selecting the element figure 3.2

In these illustrations the order in which the letters were arranged was selected to minimize the waiting time for the letters used most frequently in drawing with the Logo computer language. The large square to the right of the menu is a drawing screen and the triangular shape inside it is the "turtle" that follows instructions to create a drawing. It is currently facing up and would move in that direction if told to move FORWARD. It can also turn to the RIGHT or LEFT to face in another direction. We must tell it how far to move FORWARD and how much to turn. With all the letters and numbers available, the user has access to the entire Logo language. The system that we used most often with the severely physically handicapped children gave them a more limited choice on the menu, but in return did not require that they laboriously spell out each computer command. This was much less flexible and eventually would have been to restrictive, but initially produced a very nice response-to-effort ratio. This kind of scanning system does not require aim as does the arrangement-in-space scheme, and therefore has the advantage of being suitable for a person who lacks fine motor control. The principle disadvantage is that one does not have random access to the choices, but must wait for the desired choice to be presented.

With speech sound analysis, of course, the waiting can be eliminated. A computer that can recognize the spoken words of a user makes it possible for a user who has any consistent speech to have random access to the computer's vocabulary even though he might have inadequate motor control for aiming.

3.2 Drawing with the Turtle:

Before considering the responses of individual children, let us examine how a simple drawing of a house might be made. Figure 3.3 shows the arrow pointing to FORWARD and the turtle has drawn the line. The distance, 3, has already been selected and the command, FORWARD 3, appears at the bottom of the screen. The number 8 is then selected and the command LEFT is given. (Fig. 3.4) Again the complete command appears at the bottom of the screen. The turtle "remembers" the side and the angle separately so that one can conveniently draw without respecifying the dimensions that remain the same.

```
 1 2 3 4 5 6 7 8 9
 FORWARD
>LEFT
 RIGHT
 ERASE
 GET
 SAVE
 DRAW!
 DON'T DRAW!
 FLASH
 CLEAR
 SOMETHING ELSE
```

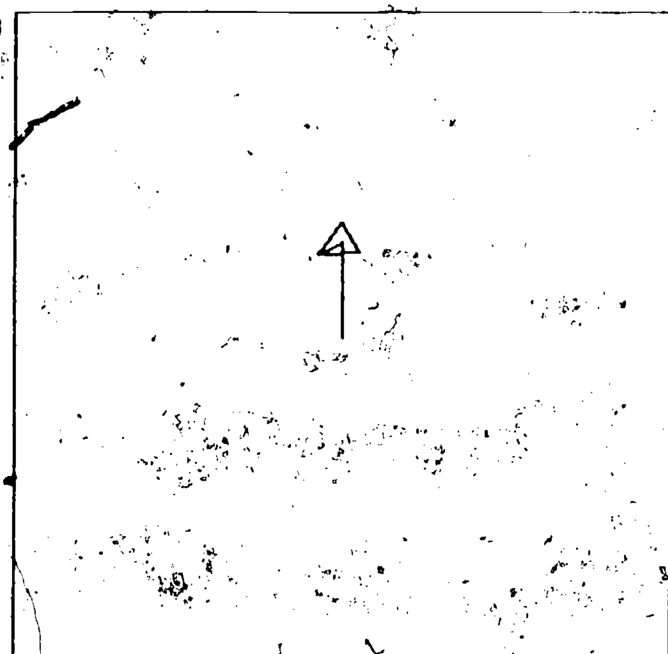


figure 3.4

THE TURTLE'S PEN IS DOWN.

LEFT 8

1 2 3 4 5 6 7 8 9
>FORWARD
LEFT
RIGHT
ERASE
GET
SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE

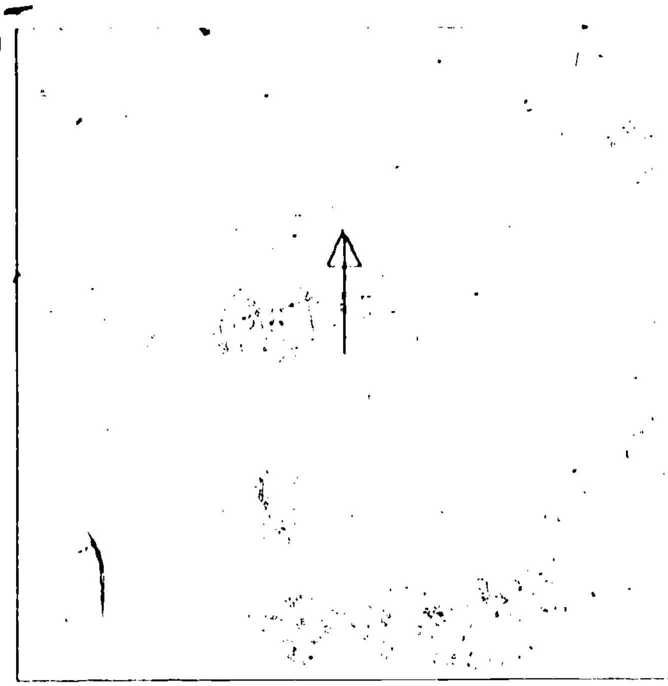


figure 3.3

THE TURTLE'S PEN IS DOWN.
FORWARD 3

Thus, the sequence FORWARD, LEFT, FORWARD, LEFT now completes a triangle. Ideally, we would like to name it, but we do not have letters available, so we SAVE the triangle as picture NUMBER 1. (Fig. 3.5) In a similar manner, we draw and save a picture of a square. (Figs. 3.6, 3.7, 3.8) Note that the angle had to be changed to a LEFT 6 and so that number had to be specified. The turtle has ended up in the lower right hand corner of the square, but it would be more convenient if it ended at the top, since we will want to put the triangle at the top to make a roof.

```
1 2 3 4 5 6 7 8 9
FORWARD
LEFT
RIGHT
ERASE
GET
>SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE
```

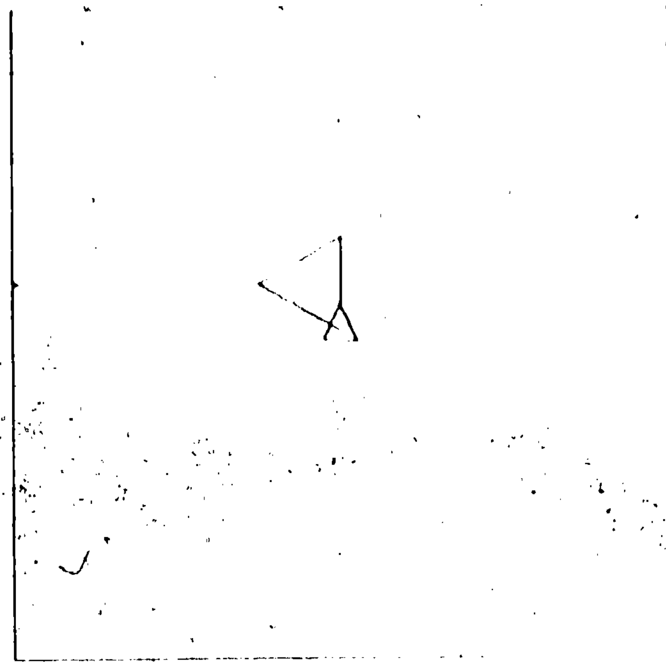


figure 3.5

```
THE TURTLE'S PEN IS DOWN.
NUMBER 1
```

```
1 2 3 4 5 6 7 8 9
FORWARD
>LEFT
RIGHT
ERASE
GET
SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE
```

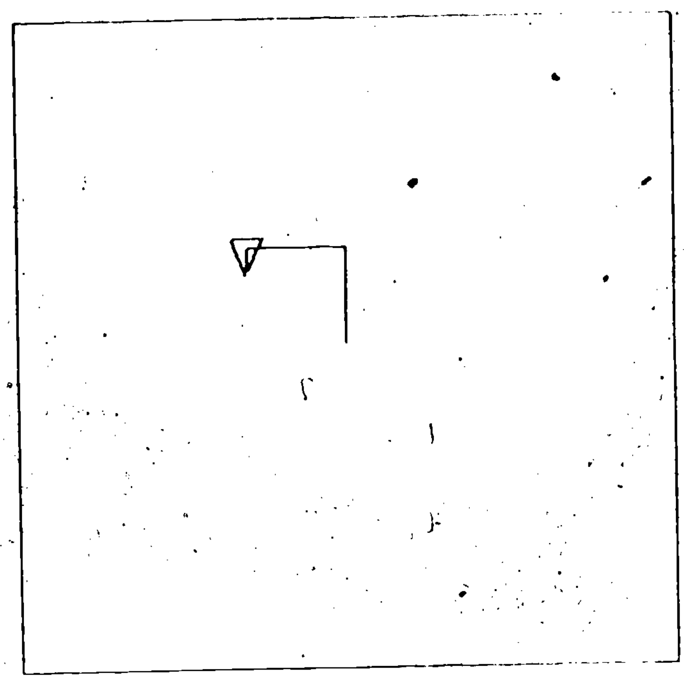


figure 3.6

```
THE TURTLE'S PEN IS DOWN.
LEFT 6
```

1 2 3 4 5 6 7 8 9
FORWARD
>LEFT
RIGHT
ERASE
GET
SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE

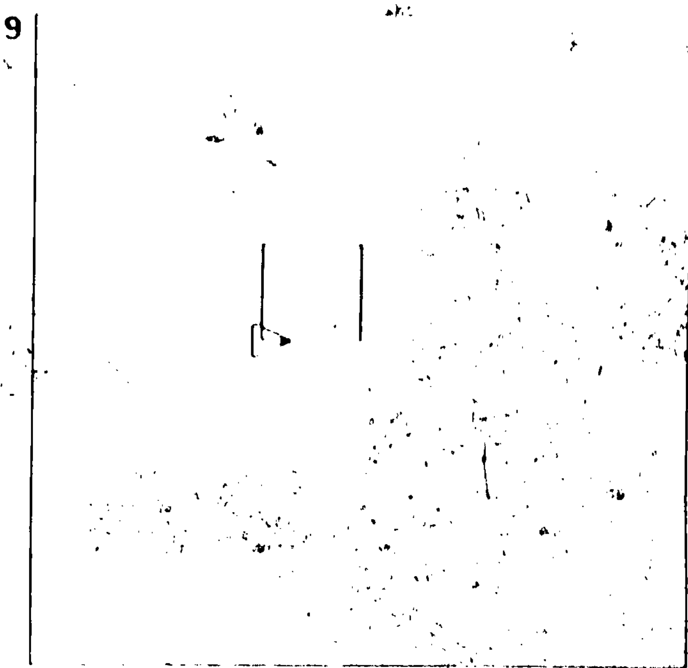


figure 3.7

THE TURTLE'S PEN IS DOWN.

LEFT 6

---

1 2 3 4 5 6 7 8 9
>FORWARD
LEFT
RIGHT
ERASE
GET
SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE

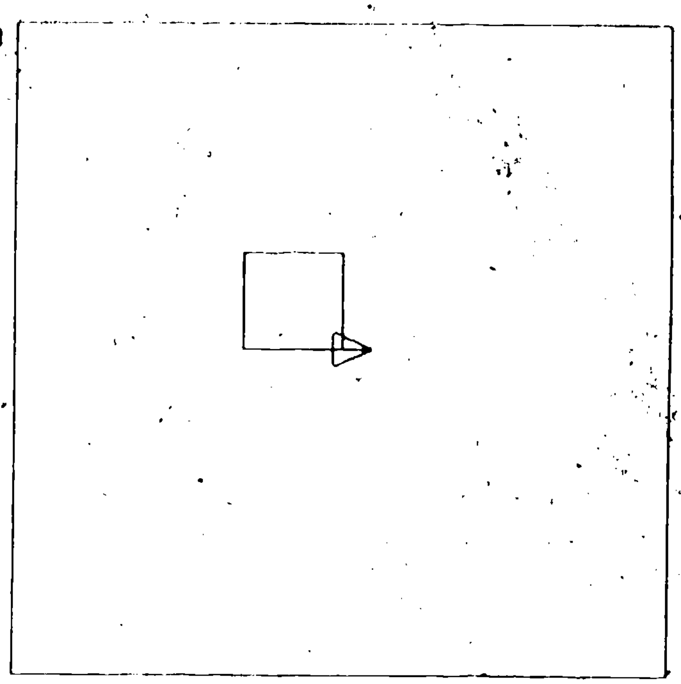


figure 3.8

THE TURTLE'S PEN IS DOWN.

FORWARD 3

So in Fig. 3.9, we begin by turning the turtle LEFT 6. Then when we GET picture NUMBER 2 (the square), it, too, is rotated 90 degrees to the left and the turtle is now at the top. (Fig. 3.10) Simply GETting the triangle (Fig. 3.11) causes a bug! The triangle is drawn exactly as it was when we saved it, so the house flips its lid. That can be fixed by turning the turtle LEFT 2 (Fig. 3.12) between GETting the square and GETting the triangle (Fig. 3.13).

```
 1 2 3 4 5 6 7 8 9
 FORWARD
>LEFT
 RIGHT
 ERASE
 GET
 SAVE
 DRAW!
 DON'T DRAW!
 FLASH
 CLEAR
 SOMETHING ELSE
```

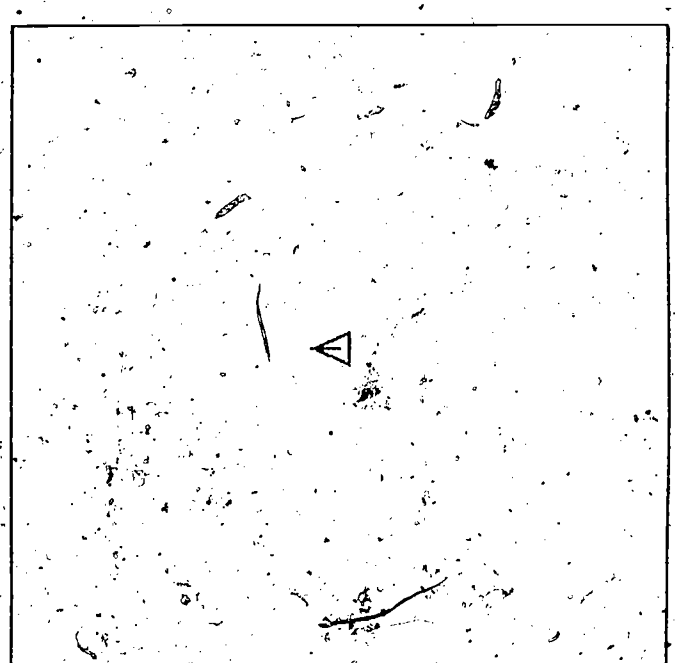


figure 3.9

```
              THE TURTLE'S PEN IS DOWN.
LEFT 6
```

```
1 2 3 4 5 6 7 8 9
 FORWARD
 LEFT
 RIGHT
 ERASE
>GET
 SAVE
 DRAW!
 DON'T DRAW!
 FLASH
 CLEAR
 SOMETHING ELSE
```

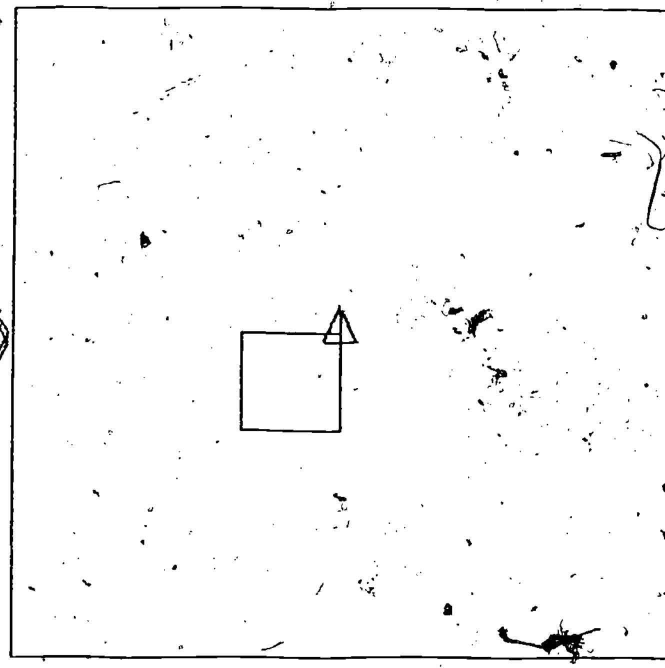


figure 3.10

THE TURTLE'S PEN IS DOWN.

NUMBER 2

```
1 2 3 4 5 6 7 8 9
 FORWARD
 LEFT
 RIGHT
 ERASE
>GET
 SAVE
 DRAW!
 DON'T DRAW!
 FLASH
 CLEAR
 SOMETHING ELSE
```

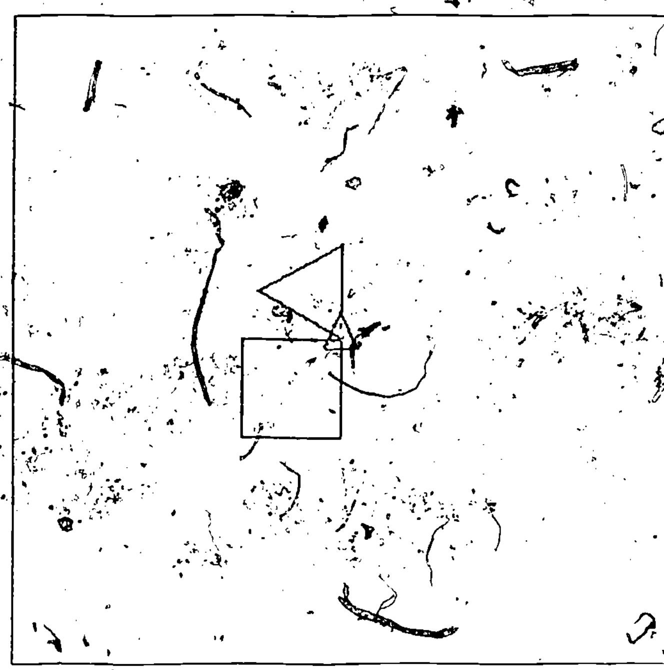


figure 3.11

THE TURTLE'S PEN IS DOWN.

1 2 3 4 5 6 7 8 9
FORWARD
>LEFT
RIGHT
ERASE
GET
SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE

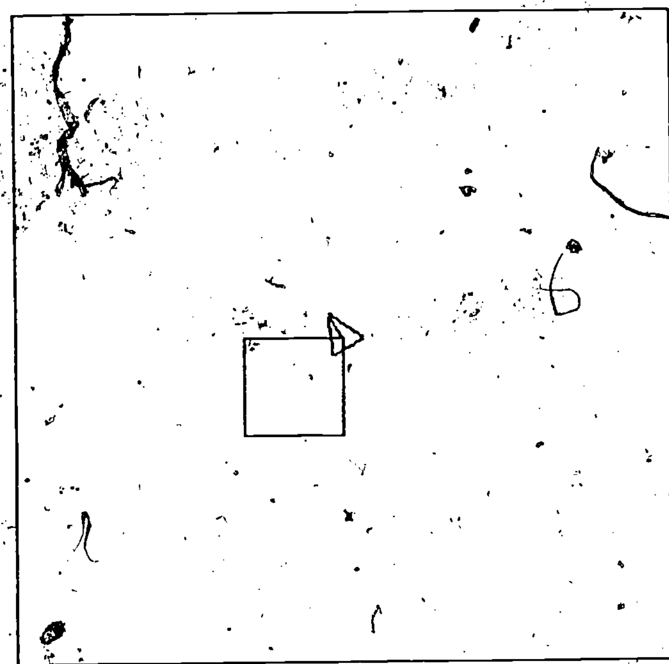


figure 3.12

THE TURTLE'S PEN IS DOWN.

LEFT 2

1 2 3 4 5 6 7 8 9
FORWARD
LEFT
RIGHT
ERASE
>GET
SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE

figure 3.13

THE TURTLE'S PEN IS DOWN.

NUMBER 1

By giving the turtle the DON'T DRAW! command, we can move it without leaving a trace. It picks its pen up before changing position and does not draw a line. (Fig. 3.14)

```
1 2 3 4 5 6 7 8 9
FORWARD
>LEFT
RIGHT
ERASE
GET
SAVE
DRAW!
DON'T DRAW!
FLASH
CLEAR
SOMETHING ELSE
```

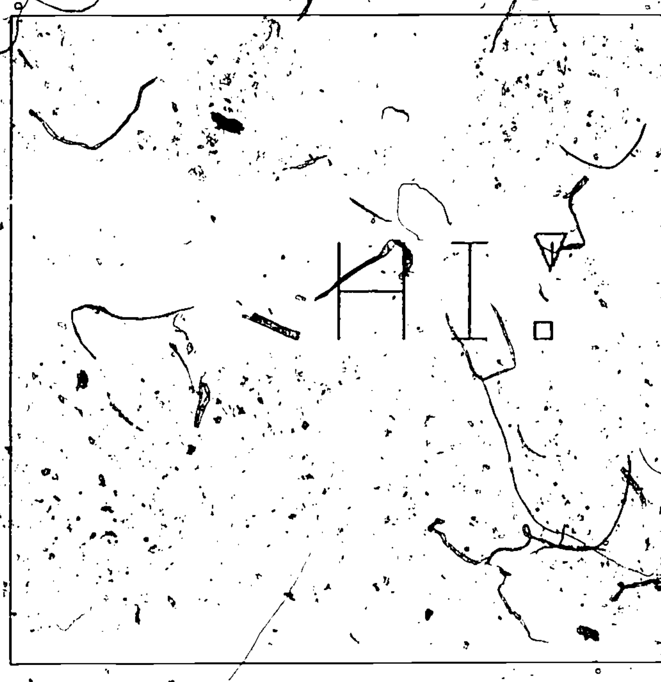


Figure 3.14

```
                    THE TURTLE'S PEN IS UP.
LEFT 6
```

Using the full alphabet, Jay created an interesting sequence of designs. The first was a lollipop shape which he called MOM. Of particular interest is the care with which he designed it. The stem was a FORWARD, but before he could have the turtle circle around to draw the top he had to turn the turtle to face perpendicular to the line he had just drawn. He chose to turn it to the RIGHT. Then, in drawing the circle, he had to make the turtle curve toward the LEFT. Had he forgotten either of these details, he would have had a very different picture. He produced the picture and then modified it slightly by changing the angle between the line and the circle to 95 degrees. It was not clear what purpose this modification served until he put four of the MOMs together to make the picture he called GOING. (Fig. 3.15) Eight GOINGs made a DADS. (Fig. 3.16) Jay then combined three DADSs to make a JAY. (Fig. 3.17) Figure 3.18 shows an intricate design created by a 12 year old girl who has never drawn before and figure 3.19 shows Johnny's wheelchair (mentioned in section 1.4).

```
TO GOING
10 MOM
20 MOM
30 MOM
40 MOM
END
```

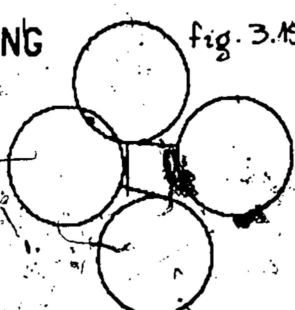


fig. 3.15

```
TO JAY
1 DADS
2 DADS
3 DADS
END
```

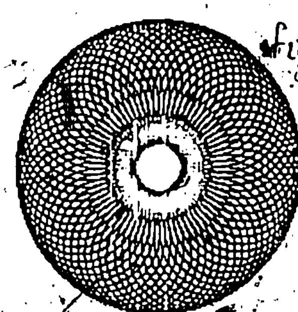


figure 3.17

```
TO DADS
1 GOING
2 GOING
3 GOING
4 GOING
5 GOING
6 GOING
7 GOING
8 GOING
END
```

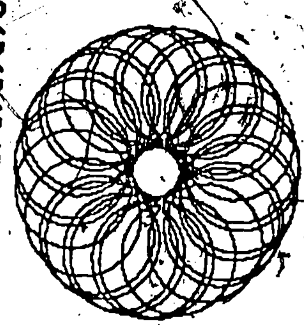


figure 3.16

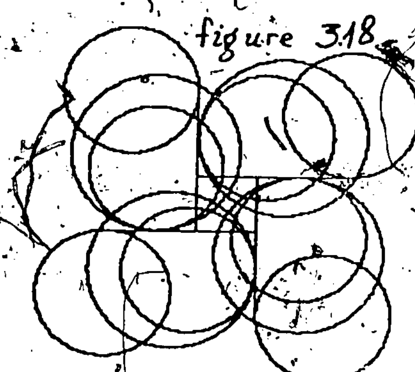


figure 3.18

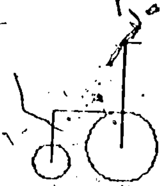


figure 3.19

4. Children Who Have Worked with Logo:

We have had enough preliminary experiences with a variety of children to feel confident that we have the right ideas and approach, if not yet the optimal implementation of them. We have worked with 9 cerebral palsied children of whom one is deaf and two of whom have aphasic language disorders. We have worked with 7 deaf children not including the one just mentioned, and 6 children diagnosed as autistic, including one who was also diagnosed as deaf. The following few illustrations describe only short experiments, for, indeed, we have not yet had enough opportunity to work with the children over an extended period of time. Even so, these samples of our experiences should serve to explain our enthusiasm about proceding with the research.

4.1 Susan -- An Adolescent with Athetoid Cerebral Palsy:

> Susan is 16 years old, quadriplegic and generally assumed to be mildly retarded. Her speech is limited, but improving. She does not use a communication board. She can feed herself slowly and can type using her right hand and a guarded keyboard. Her reading and arithmetic are both at the primary grade level.

When Susan first saw the equipment on her ward, she wanted to try it out. She could not, at first, because there were already other children working with it and because the equipment that would allow a person with such severe physical disabilities to operate it adequately was not working properly at the time. So Susan watched whenever she had the chance. When she finally did get the chance to control the computer, she had already seen the physical floor turtle move around and had heard little pieces of my explanation about how to move it. We had no adequate guard for the typewriter and so arranged a scanning system similar to the one described above to help her communicate with the computer. At that time, we had no TV graphics display and so we had to use a mechanical scanner. The instructions to the turtle were written in one column on a piece of paper and the numbers from 1 to 9 were written in another column. This paper was inserted in a flatbed plotter so that the plotter could point sequentially at the items in one column, scanning from the top to the bottom and then beginning back at the top again. When Susan wanted to send a particular instruction to the turtle, she had to wait for the plotter to point to that instruction and then hit any key on the teletype. If she wanted the turtle to go forward a different distance (or to turn through a different angle) than it did before, she had to first select a number and then give the command. To select a number, she would wait for the command NUMBERS, select that, and the pointer on the plotter would then slide over to a different column which had only numbers in it. After she had chosen a number, the pointer on the plotter would automatically go back to the command column to allow Susan to choose what action the number would be applied to.

Offered the choice of making the turtle draw for her or using it to knock down a tower, she chose to draw. I had been told that Susan could not read the particular words that were on the list of commands and so, at first, I read each command as the pointer pointed to it. I was not thinking much about what the turtle was drawing and assumed that her initial play was essentially without a plan. Having chosen the largest number for both the turtle's distance forward and the turtle's turn to the right, Susan made three lines -- a line followed by a very sharp turn to the right and another line, a very sharp turn to the left and a third line. I commented that she had caused the turtle to draw an N, Susan's last name initial. She seemed *very* pleased and moved the turtle far off to the left of the N. After selecting a smaller number to shorten the distance that the turtle would go forward each time, she began drawing again. At first, I thought she was going to make a smaller N, because she left the angle the same. She made an N-like design and then diminished the angle that the turtle would turn. Systematically, she made short lines and gentle turns, first to the left and then later to the right to draw an S. *Her initials – SN!* Total time from her alleged inability to read the commands to the completion of her surely planned and very non-trivial task: about 30 minutes.

4.2 "Aren't you happy at me!" -- A Disturbed Five Year Old:

> Nancy is 5 years old with original diagnoses that include early childhood autism. Although that diagnosis is now in question, her behavior and communication are quite clearly very disturbed. At times she appears lost in a world of her own and she sometimes talks to objects or people in that world. When she speaks, her wording is often idiosyncratic and her inflection stereotyped. When she entered the unfamiliar surroundings of our laboratory, she was clutching onto her teacher with her left hand and pinching her eyes shut with her right.

I showed Nancy the TV-turtle. Since Nancy is a very young child and a non-reader and since her handicap was not physical, I thought she would do best with the "slot-machine" as an input device. Each instruction is shown in ideographic symbols on a plastic card which she could insert in a slot in the machine. When she has assembled a sequence of such cards, she could press a button and all of the instructions would be run. She played with this for a few minutes but showed no particular interest in it. With a felt-tip pen, I drew a simple house on the TV screen, to suggest something she might like to draw. Apparently, it suggested the use of the pen only, and so she drew her own symbols on the cards, and occasionally on other pieces of equipment.

But drawings on a screen are not touchable, and the connection between a card and its effect is not immediate or transparent since one must wait for a whole sequence of cards before starting a program. Conjecturing that the whole process was too distant and symbolic for her at that time, I showed her the floor turtle and placed a teletype on the floor right next to the turtle so that she and the turtle could "live in the same world." To control the turtle, all she had to do was press F for forward, R for right turn, L for left turn, T for toot, etc. She knew her letters and I naively did not assume any need to label the special keys. She was interested but had difficulty keeping track of the keys that produced an effect. I put stickers on each special key. Each sticker showed only the same letter as the key it covered; but the white sticker with a red letter on it was enough to draw Nancy's attention away from the other keys. She still played with other buttons, but now appearing to do so rather deliberately. She would press F several times, looking at the turtle, and then would press (unlabeled and functionless) M once or twice, again looking closely at the turtle. After a while of active and very clearly interested play (and some enthusiastic comments), she made a label for the M button just like the labels I had made for the other special keys. She then tried playing with the various labeled buttons again. Her attempt to give M a function was so very clear. The experiment gave her a great deal of information that my previous explanations had failed to convey -- she stopped most of her playing with unlabeled buttons and restricted her activities to the ones she knew had an effect. It was also clear that she could cause actions that she liked by pressing the right buttons. As she gave the turtle commands to come and go and toot, I narrated the imaginary script — "you are making that turtle come to you." She directed the turtle to knock over a tower of small wooden blocks, to come to her and "run away" from her and even to "talk" (toot) to her, at her command. (The descriptions of the turtle's behavior, that is, "running away" or "talking" were usually initiated by me, but she seemed to enjoy my chatter and occasionally picked up on it herself.) *She was communicating her own ideas to that turtle and she could see consistent and clear responses to her communications.* This power was real; she could see it! Her interest and involvement were easily apparent to me and her teachers, as she became more active and was more in control, both of herself and of the turtle than she had been earlier. She also said, several times, "I'm so happy at that turtle. That turtle listens to me. Aren't you happy at me!"

4.3 Joey's First Words

> Joey is 12 years old. He is diagnosed as autistic and "probably deaf." It is reported that he has never spoken, but he makes certain sounds repetitively at times. He does not respond to sudden loud sounds, but then neither does he respond to cuts, scrapes and bruises, even ones that can be assumed to be fairly painful. He does not have the common autistic hand or face mannerisms, nor does he "look through" people as autistic children are famous for, but he does tend to ignore personal contact and withdraw from others. Some people working with him guess him to be bright, though nobody is in a position to say how bright.

When I worked with Joey, I occasionally signed to him despite the lack of any evidence that he understood sign language or was even watching me. I was also constantly narrating everything that I was thinking for the benefit of his teacher who was sitting nearby and to help make our videotaped documentation a little more intelligible than it would have been without a sound-track. We began by working with the floor turtle. Joey had pushed the keys on the teletype for a short while, long enough to see that the turtle could be controlled that way, and then stretched out on the floor near the turtle, leaving me at the teletype and resting his feet against my knees. His interactions with the turtle were now physical and direct. He made it draw by pushing it around with his hands. When, shortly, the pen fell out, he turned the turtle upside down carefully, and studied the inside. During this time he did not push the turtle around, but tried repeatedly to get the pen back into its clamp, presumably so that he could continue to draw. Once, he succeeded in getting it to stay in for a few seconds and immediately began pushing the turtle. When the pen fell out again, he stopped pushing and tried to reseat the pen. Another time, he seated the pen securely, but not in contact with the floor when the turtle was right side up. He did not push the turtle then, and seemed for a moment to have given up, but after a while he tried again to adjust the pen. It was very clear what his intentions were and that he was willing to spend time and effort to realize them. It took him almost ten minutes of careful and repeated and mostly unrewarded effort before I offered to help. He held the turtle up for me, while I adjusted the pen. When the pen was finally in, Joey began pushing the turtle in circles. I said "I wonder what happens if I pick the pen up" and, from the keyboard, I withdrew the pen from the floor. Joey seemed not to notice at first, and I commented for the video-tape, "He didn't notice...he didn't notice." Joey said "Down!" and repeated the word several times, until I made the pen go down. He did not push the turtle until I got the pen back down, at which time he became quiet for a moment and then *spoke again*. The words were muddier this time, but sounded very much like "Thank you." *Joey spoke his first words on videotape* and then went silently back to pushing the turtle.

What seems most impressive is the possibility that the turtle might serve as a useful intermediary between Joey and a therapist or teacher. Joey can relate to that machine, and it is a *relationship that can be shared with another person*, as indeed happened in this example. It is also a relationship that can change and grow with Joey, since the computer's use and behavior can be determined entirely by Joey and his teacher.

4.4 An Autistic Boy -- When is Perseveration not Perseveration?

> Kevin is 11 years old. He is also diagnosed as autistic. He is clearly quite bright, and his arithmetic and spatial perception are both excellent as is his reading. Although his speech is often communicative, it is unmistakably the stereotyped and formal speech so often noted in autistic adolescents. It is not always possible to make Kevin "hear" what has been said to him. His behavior shows the rigidity and perseveration characteristic of autism and his attention span is described as short.

One cause of perseverative behavior is fear of new choices, comfort that the current behavior is understood and safe. It was not obvious that this was the principle cause of Kevin's perseveration (as it very often is among mentally retarded adults), but it seemed to be so. For Kevin, the computer offered chances to perseverate without being bored or behaving inappropriately. Importantly, it also offered the opportunity to play with new behaviors in a context that was relatively safe. The activity we began with was an aim-the-arrow game on a TV screen. There was a small bullseye in the center of the screen, and somewhere on the screen an arrow pointed in some random direction. Kevin would command the arrow to point right or left and, once it was aimed at the target, would tell it what distance to shoot. If his aim was correct and he estimated the right distance, a bell would ring and he would score a point. He had to specify angle changes in degrees right or left, and the distance to shoot was measured in hundredths of an inch. He had had no geometry training before, and did not know any angles' measures and did not seem to understand angle measurement well. Thus when he gave turning instructions to the arrow, he was perseverative and tended to use only large numbers that ended with 5, like 165 and 155 which were his favorites. In fact, that did not matter, since enough of them did tend to aim the turtle and he had the patience and interest to repeat the commands many times. When the turtle was very well aimed, he would stop turning and shoot. This was not the only way he showed that his obviously perseverative behavior was nevertheless mindful of a goal. On occasion his teacher and I would show him new angles to try, like 45, 90 and 180. He tried some of them but for a long time he would return to 165 or some other angle afterward. The only time that he would consistently use an angle that was not in the mid hundreds and ending with 5 was when the aim was very close but not quite on target. He could then be convinced (but never at other times) to try a small number like 11 (his age). His use of his special numbers was less appropriate for estimates of distance, since each time he shot, the arrow was placed in a new place. He could see that some simple changes in his behavior (the distance he chose, for example) would produce a desired effect (hitting the target more often). He began using a ruler to measure the distance to shoot the arrow rather than guessing the distances all the time. Over the course of approximately *an hour and a quarter* of enthusiastic playing, he became more and more deliberate in his use of angle as well as in his distance judgment, and he built up a considerable score.

4.5 Thomas -- Maps and Phone Books:

Thomas is nine years old and autistic. He attends a special class along with six other autistic or autistic-like children. His teacher describes him:

> At the beginning of each morning, the group is situated around a table as we begin the group language lesson. Tom...[has] no idea of what is happening around [him]. Tom responds only when called upon and in most instances [only after I prompt with] two or three repetitions of the desired response.... Tom screens out everything, interacting only upon request and withdrawing back in his own world. [He]...has an extremely short attention span and is able to answer 60% of the time correctly after being cued several times.
>
> Communication is extremely difficult. For example, when Tommy has reached his primary frustration level he purses his lips together and will pinch your arm. Peak frustration level involves crying and pinching, both of which subside almost as quickly as they came when interaction is halted.[10]

His academic ability is beyond his apparent use for it: he is reported to flip quickly through the *TV Guide* and have read and memorized all the TV specials and movies for the week. He also remembers details of car trips and map directions phenomenally well. His special interests are hand calculators and telephone books.

He was brought to the Logo Group with two other children from his class. Our intention was to have the physical floor-turtle ready, as its physical presence and real movement seemed more easily perceivable and less abstract than the screen drawings, but problems prevented its use. We had already set up some drawing programs to allow the children to make lines on the screen regardless of what keys they pressed on the teletypes. Indeed, Tommy did not seem at all interested in the screen, but after just randomly (?) pressing a few keys, he began to type seriously. As he typed each letter, he would say the letter in a tense, strangely mechanically intoned voice.

METHUENMALL MACDONLADS BURGERKANG SEARS

I am not familiar with Methuen Mall, and therefore do not know if those stores were from that shopping center or not. It didn't matter. He repeated the typing and spelling over and over, clearing the line if he made a typing mistake and repeating the same spelling errors. He never once pronounced any of the words he had typed, but he said every letter. The computer went down. I raced off to restore it. When I returned, a teacher who accompanied the children down was trying to attract him back to the computer, but Tommy was heavily into a telephone book. "Ignoring" Tommy, I sat down at the computer and typed METHUENMALL. I read the word out loud and wondered audibly what word should follow it. Tommy left the telephone book open on the floor and sat on my lap, grabbed my hands, placed them on his stomach and continued the typing, again saying each letter as he typed it. I began to recite the letters along with him. At first, I used "my own" voice, saying each letter with the slightly rising inflection that I normally use when listing things. My syllables were short, and each began louder than it ended. He continued his chant, each letter drawn out on one pitch, at one intensity, unchanged and unchanging.

I decided to try the drone myself. When I copied his chant exactly, he reduced the tension in his voice. His syllables became shorter without being clipped, he dropped the intensity during the vowel, and allowed his pitch to drop, too. If I stopped speaking with him, he would go back to the mechanical drone. But if I continued to spell with him, using *my own* voice at this time, he would spell several letters in a clearly normal voice -- one I had never heard him use! He would return to the drone after a few letters, and, again, would stay droning if I persisted in using my voice or otherwise did not drone with him. At one time, during, BURGERKANG, he said the A with a very questioning voice. I said "I?" and he cleared the line and typed the correct spelling. He got up, went over to the phone book, looked at it without touching it, returned to my lap and correctly spelled MCDONALDS. The phone book had been open to that page all along. Frequently, when he finished a word, he would flutter his hands in front of his eyes. He seemed pleased at these times. If I tried to copy that he would grab my hands and place them on his stomach again. Much of the time, he would rest his cheek against mine and occasionally, with apparent excitement, took my hands and made them squeeze our two heads together gently. In what ways was the computer better for him than an electric typewriter, I occasionally asked myself, since he was not making any use of the drawing or other features. But he showed the answer himself as he learned how to clear the screen to hide all of his past work and get rid of any mistakes he made.

4.6 Annette, a Frightened Girl:

> Annette is 14. She is a pretty child with an engaging smile, bright eyes and no visible handicap. She has severe language and moderate learning disabilities including weaknesses in space perception, some apraxias and astereognosis (poor tactile discrimination and/or recognition). She can match pictures of objects and reads at about a first grade level, though with some marked syntactic weaknesses (as measured by arranging printed words into a sentence). Her speech is very limited, both in extent and in clarity. I have not yet heard her say more than two words in a single utterance. Yet, she enjoys signing and seems greatly to prefer it to speaking. Her record states that in a test situation that required her to respond verbally, she became frustrated and was twice near tears, but when in another testing situation it was not necessary for her to talk, "she smiled a lot and really appeared to enjoy herself." She can add on her fingers and was learning the order of the alphabet the first time I met her. Though her diagnoses have included behavior disturbances and mental retardation secondary to brain damage, her language processing is so weak that it is difficult to be certain about the extent of her potential.

Unlike the other children for whom there is a relatively circumscribed handicap that the computer bypasses or ignores, Annette goes slowly with everything. The most pressing problems, however, seem to be her disability with language and her low image of herself as a learner and we can deal directly with those. We must bypass the language problem in much the way that we do with the autistic or deaf child by presenting the minimum language needed for the project desired. For Annette, pictures or ideograms might be better than letters, despite her ability to read, to minimize the threat that comes with anything academic. Working with her was difficult, as she is very frightened by new things. She and I personally get along nicely, but she could not get near the computer without another girl, Linda, along. Linda acted as a kind of prosthetic for Annette, actually doing the typing while Annette kibbitzed. The pairing was especially intriguing since Linda has a physical handicap but is less academically retarded than Annette. I attempted to continue working with Annette in this way, with a friend, but she was brought alone to the next session and would not try anything, apparently fearing some kind of a test was involved. Just as Joey could interact with me only through the machine, Annette seems to be able to interact with the machine only through a friend. Still, the interaction was real. She was designing the experiments to try and watching the results eagerly; two behaviors that are unusual for Annette and reveal aspects of her mind that are otherwise very much hidden.

"Mental retardation" is a term which refers, vaguely, to a low level of functioning. The notion that it is a unitary condition, "the cause" of the low level of functioning, is wrong, explains nothing, and impedes progress in the education of the mentally retarded. It would be delightful to discover that Annette's handicap is due to nothing more than the combination of severe language handicaps and associated severe emotional problems. This would give us a better idea of how to treat her, but even if we cannot get a more detailed or accurate picture than that provided by the diagnosis of MR, we need not be disappointed. *Her* problem, as opposed to *our* problem with her, (and this really applies to every one of the children I've described as well as every child and adult I have not described) is having a rich and interesting and esteemable life. That must certainly be enhanced by seeing oneself as a communicator and an effector.

The communication difficulties that Jonny (section 1.4), Jay (section 0.3), and Susan had were primarily neuromuscular. They all had language and communicated. They attended, understood what others said, and spoke or typed their ideas. Nancy, Joey, Kevin and Annette have severe language handicaps. For Joey, no form of communication currently works and all four have great difficulties communicating, focusing their attention and controling themselves or their environments. If we are to help them to communicate with the computer -- and via the computer, the world -- we must take these problems into account. An input device directly sensitive to the child's proximity would facilitate initial contacts. With such a theremin-like input device, approach and avoidance with no other deliberate action can cause an effect. The output device must also be easy to attend to peripherally. A 36 square foot color TV screen on which one can draw in full color allows a very large effect for a very small effort. As the child becomes more interested in whatever output device is used (robot turtle, color TV, music box), the input device must be modified to allow greater flexibility. It must become less sensitive to the child's gross movements and allow deliberate choices while the child stays near or in contact with it. The gradual narrowing of the window through which the child communicates involves a kind of behavior shaping, but without the having the sense of programming, controlling the child. Whatever communicative efforts the child makes throughout this entire process occur only at his own discretion and express only what he chooses. Both the regularization of communication (the machine responds very predictably) and the lack of demand (the machine never even *seems* to want something from the child) may help the child learn how to communicate more freely.

5. A Plan for Research:

The grand vision is clear. Some of the particulars -- which environments might particularly suit which children -- are also known. But a great deal of work remains to be done. This kind of investigation leads us near the frontier of work with the handicapped. It also requires a state-of-the-art technology and new pedagogical assumptions and skills. Finally, the children themselves may furnish a wealth of surprises as they begin to engage in activities they had never dreamed of, and sensitivity to them may lead to research in directions other than those suggested in this paper. Environments must be designed that allow us to test out the basic assumptions. The designing of these environments is a clinical task, tailoring hardware, activities and pedagogy to each individual child. At the same time, it seems important to do early responsible explorations into the directions that computer-based habilitation and education centers might go in the future.

An application of this kind of technology to vocational habilitation is also important to mention before outlining the specific research that must be undertaken during the next several years.

One Student's Experience

The problems and the potential are illustrated by our work with Jay, a cerebral palsied adolescent with no effective use of hands, legs or speech. Before the experiments started, Jay had been experienced in the use of a head-stick with which he could type, though slowly and inaccurately, on a electric typewriter that was specially modified to have recessed keys to guard against accidental key-pressing. After only one day (approximately 3 hours), Jay's teachers noticed a vast improvement in his typing ability. In three days, Jay had learned enough Logo to draw some very handsome pictures. The interest of these events is greatly increased by the fact that Jay's intellectual potential had previously been assumed to be extremely low. Jay's experience with the computer demonstrated for the first time a high level of analytic and of spatial ability. Indeed, some puzzling problems for developmental psychology are raised by the fact that a person who had never manipulated objects or drawings could perform so well a task requiring quite sophisticated spatial reasoning. The case study was conducted in a very informal exploratory spirit but nevertheless makes it quite obvious that more work in this direction could be extremely interesting for theoretical psychology besides being of more immediate practical value from an educational and humanitarian point of view.

The Promise

Jay's achievements after [a short time were already significant].... But the image we want to create here of the possible value of access to the computer is qualitatively very much more than even this. To develop it we have to ask the reader to grant that if Jay could learn any significant piece of programming skill in a few days (and on our first presumably clumsy attempt at teaching someone like him) then he could come to a high enough degree of proficiency in the course of a few years to be employed as a professional programmer. Naturally, this suggestion raises many questions about the broader education he might need to operate effectively as a computer (or other) professional and the material conditions which would make it possible for a person with his disabilities to interact with a work world. We claim that our present state of knowledge makes these all routinely researchable questions to which one can expect with reasonable confidence to have acceptable and demonstrated solutions within a few years. [Goldenberg and Papert 1976]

5.1 What Needs to be Done:

Following are three specific areas in which work is needed.

5.11 Equipment Development:

In the past several years, a variety of electronic communicators have appeared. [Luster and Vanderheiden 1974] Responsible developers who have stressed the service component of their work have cared not only about the conceptual function of the devices, but also with the sturdiness, reliability, maintainability, ease of use and attractiveness of the communicators. The ideas was to provide a person such as Jay with a communication system which can be installed, in its entirety, in his wheelchair, to be his property and stay with him, just as his eyeglasses do. It was also deemed important that the user be able to use the aid flexibly in recreational, educational and vocational settings. Only with the recent availability of inexpensive, powerful, *small* computers could some of these goals be realized. Smart communication devices can anticipate the user's needs while making good use of the user's capabilities. The flexibility to have er-variable choices on a direct-access lap-tray is part of the Autocom (Vanderheiden) and the TIC (Foulds) makes use of English orthographic statistics to abridge the time needed to spell a word. But the microcomputer makes possibilities open up which were not even conceivable before. The ultimate communication device should provide capabilities for speech and graphics and music and locomotion in addition to the production of voice or text. If it is to be therapeutically sound, it must make use of the person's strengths in such a way as to increase his independence. Recall, for a particular example, the therapeutic use of the spoken word recognizer. (See section 2.23) Also, the fact that a computer can make communication not merely possible, but quite practical offers the motivation to expand that communication beyond the expression of physical or work-related needs. It should be pointed out that the technology necessary to implement this dream is all currently available, though not yet assembled and utilized in the optimal way. Thus, this dream does *not* depend on some future development whose timetable is as yet unknown. The equipment development program would be dependent on the goals and findings of such research as is described below and would stress the building of an optimal device rather than the adapting of some device that had originated for some other purpose.

5.12 Research and Development in Psychology and Pedagogy:

Curricula that currently exist have what might be called cultural biases against people like Jay. They tacitly assume a very large set of experiences that Jay has not had. If we try to teach him without being sensitive to this fact, we may misinterpret his failures as indicators of his potential rather than indicators of his readiness. The fact that this kind of error can be made is illustrated well by Jay. Because Jay was *able* to type, and because he *still* showed very limited intellectual performance, some of the people working with him considered it safe to accept mental retardation as part of his diagnosis. If any part of the normal child's difficulties with math comes from his view of it as a useless exercise, how much more true that must be for someone whose major life issues have always been trying to communicate where you hurt or when to turn on the TV. Though it comes as no surprise that there are children whose intellectual potential remains largely undiscovered, each child that we work with makes it painfully clearer that the number of children whose mental life has been written off may be *vastly* greater than the most optimistic of us have ever guessed.

Research must also be directed toward understanding where some of Jay's surprising *abilities* come from. Jay's sensitivity to angles and dimension (though he has never physically manipulated these variables) needs more study. We need clearer pictures not only of what is *lacking* in the handicapped child's mental map of the world, but of what is *present*. Research in the spirit of Piaget and without our cultural biases is certainly needed.

Some specific experiments in education and habilitation must be tried. A child's progress in breath control may be a clear milestone to a trained speech therapist and still go totally undetected by the child who hopes to learn to speak. The spoken word recognizer may provide a tool by which the child can gain feedback and put his vocal efforts to use. The pleasure in control and the confidence that progress is possible -- not to mention the constant practice that are an expectable consequence of that pleasure and confidence -- should vastly increase the success of the therapy. Experiments to verify this conjecture are needed.

5.13 Experiments in vocational training:

Thought must be given both to the kinds of jobs that would be suitable for a person like Jay or Lisa. Consideration must be given not only to the physical manageability of the job, but to the personal satisfaction that one can gain from it. Occupations involving the manipulation of information and which do not require much physical mobility or manipulation come to mind. For example, computer programming can be done at one's own home if mobility were a problem. Similarly, reference library work and manuscript editing can, when needed, be carried out remotely. But we cannot blindly assume that by providing communication equipment alone, the remainder of educating these clients for their jobs will follow a normal course. As with other curricula, we must realize that the student's real handicap is his relatively diminished ability to adapt to our failings in teaching and that we must therefore tailor both mode of presentation and actual content in reasonable ways. This calls for a careful analysis of what knowledge and abilities are really necessary for a particular job and must of course account for the non-normal background of the student.

For example, *pairs* of people who might singly remain unemployable can potentially be employed together in innovative ways. The physically handicapped person who, despite the aid of a computer still needs considerable physical aid and care in order to interact successfully with his work environment may in some cases be provided that aid by a retarded worker whose employability and social contacts would otherwise be limited to the sheltered workshop. Thoughtful efforts must be made in developing an appropriate educational program to help a retarded person assume such a role.

5.2 Clinical Use and Demonstration Centers:

Experiments "*in vitro*" as described above have the technological flexibility and staffing to have the wildest dreams and make them come true, but do not have the variety of users (both students and teachers) that "*in vivo*" experiments do. The latter offer more feedback on the clarity of the curriculum, the generality of its usefulness or interest, and the suitability of the equipment. In addition, the different perspective of field users may furnish a wealth of ideas that are not so readily gained in a laboratory setting. The practical considerations of packaging an economical, physically stable, and easily exportable system for general use with severely handicapped children must be examined closely, and so it will be necessary to form close working relationships with treatment centers and schools such as Crotched Mountain Center.

NOTES

1. Our experiences with severely physically handicapped children raise such important questions as these: How *active* must active be? How *much* of a child's experience must be physically active for him to create an internally active mental model?

2. One such experience is mentioned briefly in section 4.2 of this paper and is recorded on videotape. The Wier and Emanuel work is also videotaped.

3. The children described are real, but names have been changed and identifying information has been changed or deleted.

4. It is interesting to note that the dominant philosophies regarding the use of sign language in the education of deaf children hardly take any note of the difficulties of visual transmission of English, whose natural modality, both historically and developmentally within each hearing person, is auditory.

5. "Voluntary motor control" can be any voluntarily controllable and measurable efferent, and need not be a coordinated movement.

6. An interesting case in point is sign language. [Markowicz 1972, Woodward 1973] Despite the continued predominance of strictly oral schools for deaf children, which seems incredible, in the light of the research [Vernon and Koh 1970, Vernon and Koh 1971], there is an increasing number of schools which are beginning to allow, or, better yet, *use* sign language. A casual look at the society of deaf adults tells us that signing is *not* merely an "interim way" for the child to communicate, and yet, for the most part, even the schools that most freely accept signed communication tend to regard the language ethnocentrically, treating it only as an auxiliary language, something which may be valued as a kind of teaching tool, but never esteemed along side of English. David M. Denton, Superintendent of the Maryland School for the Deaf, must certainly be considered one of the strongest and most conscientious supporters of total communication for deaf children. In an article supporting its use [Denton 1970], he quotes the definition of total communication: "By total communication is meant the RIGHT of a deaf child to learn to use all forms of communication available to develop *language competence*. This includes the full spectrum, child devised gestures, speech, formal signs, fingerspelling, speechreading, reading and writing." (my italics) Perhaps no special emphasis was intended when "*language competence*" was chosen instead of something like "*intellectual strength, the knowledge of self-worth and social fluency*," but neither have I seen explicit acknowledgment that language is not an end, but a means (except among the radical fringe -- I know of only one such who is a supporter of Ameslan [Fant 1974]). It is rare for sign to be taught deaf children with the same deliberate care and pride that characterizes the teaching of English to either hearing or

deaf children

7. Personal communication from Clinton Hilliard, Director of Communication Therapy at Crotched Mountain Center, Greenfield, New Hampshire.

8. I will often have occasion to use the word "program." The word always suggests *planning* whether one refers to a remedial reading program or the technical sense of a computer program (procedure), but I will use it consistently with the non-technical meaning, suggesting the idea of a language arts program, a TV program, or an after dinner program -- always like an arrangement of events, a menu or performance and never like the work of a computer programmer. That latter item -- a set of instructions to be followed by a machine or a person -- will be referred to consistently as a procedure. (Indeed, a computer might "put on a program" just as a dance troupe might, and each would execute one or more procedures to do so.)

9. Wier and Emanuel [Wier and Emanuel 1976] refer to the "passive pupil role" and the "emotionally committed role" of their autistic student, David. When David was being taught, when the agenda was not his and the activities were not thoroughly within his control, he "acted autistic" and assumed the passive role. When *he* was the agent, the researchers observed increases in appropriate spontaneous speech, improvements in vocal tone, changes in body posture signifying interest and involvement, and obvious pleasure.

10. Personal communication from Daniel Marshall at the Easter Seal Society in Manchester, New Hampshire.

REFERENCES

1. Austin, H., "A Computational View of the Skill of Juggling," *Artificial Intelligence Laboratory of Massachusetts Institute of Technology,*

2. Boothroyd, "Use of Computer Based System of Speech Training for Deaf Persons," *Volta Review*, 77(3), 1975

3. Brudny, J., Korein, J., Levidow, L., Grynbaum, B. B., Lieberman, A. and Friedmann, L. W., "Sensory feedback therapy as a modality of treatment in central nervous system disorders of voluntary movement," *Neurology*, 24:925-932, 1974

4. Colby, K., Rationale for Computer Based Treatment of Language Difficulties in Non-speaking Autistic Children, *Joufnal of Autism and Childhood Schizophrenia*, 3(3), 1973

5. Deacon, J. J., *JOEY*, Charles Scribner's Sons, 1974

6. Eulenberg, J. B., "Individualization in a Speech Prosthesis System," Paper presented at the Conference on Systems and Devices for the Disabled at the Tufts New England Medical Center, Boston, Mass., June 1976

7. Fant, L., "Ameslan: the Communication System of Choice" in Fine, P., *Deafness in Infancy and Early Childhood*, Medcom Press, 1974

8. Fletcher, J. D. and Beard, M. H., "Computer-Assisted Instruction in Language Arts for Hearing-Impaired Students," *Psychology and Education Series, Institute for Mathematical Studies in the Social Sciences, Stanford University*, Technical Report No. 215, 1973

9. Foulds, R. and Gaddis, E., "A Practical application of an Electronic Communication Device in a Special Needs Classroom," *Proceedings of Conference on Devices and Systems for the Disabled*, Krusen Center for Research and Engineering, Temple University Health Sciences Center, Philadelphia, pp. 77-81, Apr. 1975

10. Goldenberg, P. and Papert, S., "Toward a Concept of Informational Prosthetics," internal document, Logo Group, M.I.T.

11. Department of Health, Education, and Welfare, Office for Handicapped Individuals *Programs for the Handicapped*, page 12, December 20, 1976

12. Kafafian, H., *C/R/I Final Report: Study of Man-Machine Communications Systems for the Handicapped, Volume III*, HEW Project No. 18-2003 and 7-0533, 1973

13. LaVoy, R. W., "Ricks Communicator," *Exceptional Child*, 23:338-340, 1957

13. Luster, M. J., and Vanderheiden, G. C., *Preliminary Annotated Bibliography of Communication Aids*, NSF Grant •EC-40316, BEH Grant •OEG-0-74-7481, 1974

14. Markowicz, H., "Some Sociolinguistic Considerations of American Sign Language," *Sign Language Studies*, 1:15-41, 1972

15. Marks, N. C., *Cerebral Palsied and Learning Disabled Children*, Charles C. Thomas, 1974

16. Nickerson, R. S. and Stevens, K. N., "Teaching Speech to the Deaf: Can a Computer Help?," *IEEE Transactions on Audio and Electroacoustics*, AU-21(5), 1973

17. Nickerson, R. S., Kalikow, D. N., and Stevens, K. N., "Computer-aided Speech Training for the Deaf," *Journal of Speech and Hearing Disorders*, 41(1):120-132, 1976

18. Papert, S., "Uses of Technology to Enhance Education," *Artificial Intelligence Laboratory of Massachusetts Institute of Technology*, Logo Memo No. 8, 1973

19. Tallman, T., "Computer Assisted Communication System," Paper presented at the Conference on Systems and Devices for the Disabled at the Tufts New England Medical Center, Boston, Mass., June 1976

20. Vernon, M. and Koh, S.D., "Early Manual Communication and Deaf Children's Achievement," *American Annals of the Deaf*, 115:527-536, 1970

21. Vernon, M. and Koh, S.D., "Effects of Oral Preschool Compared to Early Manual Communication on Education and Communication in Deaf Children," *American Annals of the Deaf*, 116, 1971

22. Wier, S. and Emanuel, R., "Using Logo to Catalyse Communication in an Autistic Child," *Department of Artificial Intelligence, University of Edinburgh*, D. A. I. Research Report No. 15, 1976

23. Woodward, J. C., "Some Observations on Sociolinguistic Variation and American Sign Language," *Kansas Journal of Sociology*, pp. 191-200, Fall 1973